Chapter 2.1 SURFACE WATER MONITORING PROGRAMS

Ambient Water Quality Monitoring (AWQM)

With the implementation of the Department's Water Quality Monitoring Strategy in the spring of 2001, a new approach to multi-layered networked programs was undertaken. Traditionally, sampling had occurred to gather information from industrial, urban, rural, and undeveloped areas of the state. These data are gathered near industrial and municipal discharges, nonpoint source areas, public water supplies, unaffected areas, and previously unassessed areas. In this way, stream miles at risk from major pollution sources are well documented, as are those where pollution risk is suspected or unknown. Regional office personnel who are most familiar with local conditions and concerns determined station locations, parameters sampled and frequencies.

By implementing the strategy, various individual programs were defined in terms of station siting criteria, parametric coverage and frequency all leading to statewide consistency.

From the Strategy:

The mission of the Water Quality Monitoring Program is to produce representative high quality data that supports the evaluation, restoration, and protection of the quality of the Commonwealth's waters for the purposes of fishing, swimming, boating, drinking, and the propagation and growth of a balanced, indigenous, healthy, natural ecosystem.

In order to achieve this goal, and satisfy scientific, legislative and esthetic requirements related to the quality of the Commonwealth's aquatic resources, DEQ has established a series of specific objectives to identify and define the diverse functions of the Water Quality Monitoring Program.

Objectives:

1. Assessment and Remediation Objectives:

(**a**) Status Quo Characterizations and Assessments:

(1) Provide accurate, representative data for water quality characterization and assessment of all surface waters within the state.

(2) Establish consistent statewide siting, parameter selection and monitoring techniques, to ensure data reliability and the comparability of data.

(3) Assure that the frequency of sampling and the total number of observations collected are sufficient to provide adequate data for scientific, statistically based and defensible assessment procedures.

(4) Assure that, whenever possible, flow rates are determined simultaneously with the collection of other water quality data.

(5) Monitor, according to a plan and schedule, all substances discharged into state waters that are subject to water quality standards or are otherwise necessary to determine water quality conditions.

(6) Continually evaluate the overall success of the Commonwealth's water quality management efforts.

(**b**) Impaired Waters / Remediation:

(7) Provide data to define the cause, severity and geographic extension of impaired waters:

(8) Provide adequate data for TMDL model development and validation.

(9) Provide adequate data, by means of follow-up monitoring, to evaluate the implementation of TMDL's and other best management procedures.

(**c**) Variability, Trend Assessments and Forecasts:

(10) Provide adequate data and analytical procedures for short, medium and long-term statistical evaluation of water quality variation and trends within identifiable, geographically defined waterbodies.

2. Permit Objectives:

(11) Provide data for the calculation of permit limits for the issuance, re-issuance and/or modification of effluent discharge permits.

(12) When water quality problems are suspected, provide data to detect and document water quality impairments and/or to evaluate permit adequacy, whether permitted dischargers are in compliance with permit limits or not.

3. Efficiency Objectives:

(13) Improve the efficiency of the Monitoring Program by minimizing resource requirements and the duplication of efforts, while maximizing the use of integrated data collected within and among state and federal agencies, public utilities, private enterprises and citizens groups for statewide water quality assessments.

(14) Increase the use of biological (e.g., benthic macro-invertebrates, fish, and/or aquatic vegetation assemblages), as well as fish tissue and sediment monitoring for specific assessments of water quality.

(15) Investigate, identify and characterize additional avenues of actual or potential water quality impairment, including ground water contribution and aerial deposition rates.

(16) Guarantee adequate Quality Assurance / Quality Control (QA/QC) procedures to provide precise, accurate and representative water quality data for all purposes.

4. Research Objectives:

(17) Provide data to validate special stream or site designations.

(18) Evaluate new methodologies for sampling, analyzing and assessing water quality.

(19) Provide data for other research objectives.

As a result of the implementation of the new strategy a monitoring network of multiple programs and special studies was identified and developed to include the following programs:

WATERSHED A Ambient watershed network of stations and represents the largest single section of the monitoring program. Detailed information on the purpose and objectives of these stations and their selection can be found in Section III.B. of the strategy.

COASTAL 2000 C2 Coastal 2000 is the federally funded tidal probabilistic program designed by USEPA and sampled by VADEQ staff. Grant funding for this program is scheduled to end in 2004.

CHESAPEAKE BAY CB Chesapeake Bay Program identified in section III.E.1.of the strategy. The design of this program is through the USEPA Chesapeake Bay Program Office and encompasses a multi-state water quality characterization effort.

CITIZEN MONITORING CMON Citizen monitoring are those stations in segments identified through public participation as targeted for specific monitoring. Public notification for requests from citizens to VADEQ to include water quality monitoring are usually a result of problems identified by the public. Notification occurs in the fourth quarter of the calendar year with sampling scheduled to begin in the next monitoring year.

FACILITY INSPECTION FI Facility inspections are not specifically identified in the water quality monitoring strategy but are integral to determining compliance with discharge limits. Specific sample locations are not included in the monitoring plan but only estimated numbers of samples for the purpose of calculating annual budgets. For more information on this program please contact Roger Stewart at (804) 698-4449.

FRESHWATER PROBABILISTIC FPM The freshwater probabilistic monitoring program covers the non-tidal free flowing waters of the state. The program is designed to answer the question of what is the overall water quality of the Commonwealth for free flowing streams.

FISH TISSUE C Fish tissue and sediment monitoring program1 conducted by central office staff from the Office of Water Quality Standards.

MERCURY HG Mercury Special Study Program paid for by the responsible parties.

INCIDENT RESPONSE IR Incident response samples are the same as PC but of non-petroleum in origin.

POLLUTION COMPLAINTS PC Pollution complaints are special samples collected generally as a result of a petroleum spill.

REGIONAL BIOLOGICAL B Biological monitoring program which focuses on the analysis of the benthic macro invertebrate community as a tool to detect water quality conditions. The methodology follows the USEPA Rapid Bioassessment Protocol II and is described in section III.E.4. of the strategy.

RESERVOIR MONITORING L Reservoir monitoring which is described in the Lake Monitoring Guidance2 available at http://www.deq.state.va.us/waterguidance/pdf/022004.pdf

SPECIAL STUDIES SS Special studies are identified by individual project plans and are generally specialized intensive targeted monitoring efforts designed to answer specific hypothesis related to water quality conditions.

TMDL TM TMDL monitoring are those stations associated with the development of a TMDL implementation plan for segments listed on the 303(d) list.

TREND TR Trend stations are those long term stations sited for permanent monitoring for the purpose of detecting short, medium, and long term water quality trends for a wide variety of environmentally important water quality parameters.

CARRYOVER TW Insufficient data stations are those stations with insufficient data for assessing and usually are those stations with small data sets during an assessment cycle that indicate a potential problem. These stations are considered carryover stations and will be sampled until sufficient data indicate water quality conditions.

Data Summary

From January 1998 to December 2002 DEQ staff collected multiple samples at approximately 4000 stations. From these stations the number of independent observations for the more common field measurements were 65,881 for temperature, 83,492 for pH, 65,610 for dissolved oxygen, 49,818 for specific conductivity, 25,897 for salinity and 5,232 for Secchi depth. These samples were analyzed by the Division of Consolidated Laboratory Services (DCLS) for 480 different parameters for a total of 1,116,807 data points.

The number of stations representing a particular type of stream segment, the types of samples collected, the parameters analyzed, and the sampling frequency all vary depending on site conditions and program emphasis. A detailed report of sample locations, matrices, parameters, and frequency is available in the Annual Monitoring Plans at http://www.deq.state.va.us/water/reports.html.

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1 Virginia Department Of Environmental Quality, Water Quality Standards, Office Of Water Quality Programs 2001 Fish Tissue And Sediment Monitoring Plan, May 9th, 2001.

2 Lake Monitoring Guidance, Virginia Department of Environmental Quality, December 1999.

Each basin summary, found in Chapter 3.2 of this report, lists the ambient water quality monitoring (AWQM) and biological (benthic) monitoring summary data within the basin. Summaries of the sampling data collected at each station during the reporting period are provided as a supplement to this report and can be found on the DEQ water webpage http://www.deq.state.va.us/water.

Trend Analysis

The Water Quality Monitoring, Information, and Restoration Act, now public law, establishes the basis for a strategy to determine water quality trends.

§ 62.1-44.19:5. Water quality monitoring and reporting. (1997, c. 519; 2000, cc. 17, 945, 1043.)

B. Monitoring shall be conducted so that it:

1. Establishes consistent siting and monitoring techniques to ensure data reliability, comparability of data collected throughout the state, and ability to determine water quality trends within specific and easily identifiable geographically defined water segments.

The importance of estimating long term water quality trends is essential to predicting future adverse conditions and measuring progress of restoration efforts. The central question that trend analysis should answer is: Are the waters of the Commonwealth cleaner than before? Although this question appears simple in its form, in order to scientifically measure trends the question becomes: Is there an increasing/decreasing or no trend at a specific location for each individual variable? The challenge is to design a network of stations to answer this question and to collect and analyze the data with this purpose in mind.

Changes in water quality over time may indicate improvement or worsening of conditions at a specific site. Water quality changes are measured on individual variables from specific sites that have large data sets. To measure trends in water quality, several assumptions are necessary to determine the statistical significance of the interpretation. The first assumption is location of trend stations. Stations are chosen to be representative of major river segments and in free flowing sections co-located with discharge gages. Stations are located at the fall line and mouth of major rivers. Stations are also selected that have a long continuous history of monitoring. Some stations have been monitored for 30 years and it is these that are good candidates for the statistical analysis of trends.

Another assumption is that sufficient data must exist to determine the significance of any trend detected. Generally stations must have a minimum of ten years of uninterrupted monthly or bimonthly data. The more data over a longer period of time increases the ability to determine significant trends.

Trends are calculated from individual variables from individual stations. Some variables may be combined, as is the case of nitrogen where total nitrogen trends are calculated from the summation of nitrate, nitrite, ammonia, and Total Kjeldahl nitrogen. Others like dissolved oxygen may have been measured by Winkler during the early days of monitoring but are now measured by probe; these are combined into a single variable.

For the monitoring year 2004, the Department has identified more than 300 stations that will be monitored indefinitely every other month.

Trend analysis is performed using a non-parametric modified Seasonal Kendall Tau test3. The analysis categorizes data in two-month time blocks beginning in January and February for a total of six blocks. Water quality values from each block are compared to the previous year's block to determine if they are equal to, greater than, or less than the current value. This is repeated for each measurement over the entire history of sample collection. The number of each comparison (+, -, =), the slope of the raw monthly values, the Tau value (correlation coefficient), and the statistical significance of the test, p value4, are determined. For

3 Long-term Water Quality Trends in Virginia's Waterways, Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University, Special Report, 1998.
4 Pearson, K. 1900. On the criterion that a given system of deviations from probable cause in the case of a correlated system of variables is such that it can be reasonably supposed to have arisen from random sampling. Philosophical Magazine, Series 5, 50, 157-172.

example if every two-month block were greater than the previous block the Tau value would be 1.0. If every block were less than the previous block the Tau would be –1.0 and if they were equal the Tau value would be 0.0. For a trend to be statistically significant the p value must be less than or equal to 0.01 and for the trend to be highly statistically significant the p value must be less than or equal to 0.001.

Although trends are calculated on single variables, summaries by basin of statistically significant trends by parameter are presented for inference only.

Data Management

Data are managed through the Comprehensive Environmental Data System Water Quality Monitoring module (CEDS WQM), an in-house Oracle database application. The process begins with the entry of field parameters by field technicians followed by the electronic data transfer of the field data and requested services to the Division of Consolidated Laboratory Services (DCLS). Analyte data are reported back to DEQ from DCLS and screened for QA/QC problems. Restricted DEQ personnel may correct, delete or erase erroneously stored data. Ambient water quality monitoring data are available on the DEQ website at: http://www.deq.state.va.us/water/monitoring.html. Data can be provided in hard copy and digital formats by contacting the CEDS WQM coordinator at (804) 698-4449, restewart@deq.state.va.us.

Hydrologic Data Gathering

The Department of Environmental Quality (DEQ) and the U.S. Geological Survey (USGS) are the primary agencies responsible for collecting hydrologic data in Virginia. The two agencies have worked cooperatively since 1925 except for a brief period from 1957 to 1967 when the two agencies dissolved the cooperative effort and operated independently. Virginia is one of four states in the Union with such a cooperative agreement with the USGS. Individually, the agencies carry out their own agendas in the collection of hydrologic data. Together, they provide a comprehensive picture of the state of hydrologic affairs in the Commonwealth.

Hydrologic data collection in Virginia began over a century ago. The oldest active stream gaging station in Virginia is on the James River at Cartersville where hydrologic data was first collected in October 1898. Since then, the number of continuous record hydrologic gaging stations in Virginia has grown reaching a peak in 1981 with 211 continuous recording gaging stations in operation. However, by 2000, funding cuts and manpower reductions have reduced the number of active, continuous-record gaging stations in Virginia to 157.

Of Virginia's 157 active gaging stations, DEQ operates 67 and the USGS operates 90. Additionally, DEQ conducts instantaneous stream flow measurements at more than 80 sites while the USGS conducts such measurements at over 100 sites. The DEQ instantaneous measurement sites are typically located upstream of the Virginia Pollutant Discharge Elimination System (VPDES) permit discharges while the continuous record gages are located primarily on larger, free flowing streams. The USGS also operates 9 gages on lakes and reservoirs that provide stage and contents data. Flow data, lake level data and other miscellaneous measurement data are published in Volume 1 of the annual report entitled "Water Resources Data Virginia", cooperatively prepared by the DEQ and the USGS.

The hydrologic data collected by DEQ and the USGS provide an essential component in the assessment of water quality in the state. The impact a point or non-point source pollutant discharge has on water quality in a stream cannot be adequately assessed without reliable stream flow data. If the stream in question does not have a continuous record gage or miscellaneous measurement site on it, the flow may be estimated by other means. However, such estimates are not nearly as accurate as field measurements or continuous gage hydrologic data.

Estuarine Probabilistic Monitoring Program (Coastal 2000)

Virginia's estuarine probabilistic monitoring module was initiated in the summer of 2000 with a five-year grant (CR-828544-01) from EPA's "National Coastal Assessment (NCA) Program", formerly known as the "Coastal 2000 Initiative". This original, five-year effort was defined under the terms of a proposal titled "Monitoring the US Atlantic Coast: Assessing Virginia's Estuaries and Tidal Tributaries to the Chesapeake Bay and the Atlantic Ocean", submitted to the US-EPA in the spring of 2000. Specific field methodologies and

Quality Assurance requirements of the Coastal 2000 / National Coastal Assessment Program are described in the EPA documents "National Coastal Assessment Field Operations Manual" (EPA 620/R-01/003) and "National Coastal Assessment Quality Assurance Project Plan 2001-2004" (EPA/620/R-01/002).

Purpose:

The original goals of the National Coastal Assessment (Coastal 2000) Program were summarized as:

- Assess the ecological condition of estuarine resources,
- Determine reference conditions for ecological responses/stressors, and
- Build infrastructure in EPA Regions and participating states.

Additional, more specific federal objectives were to:

- Assess the health or condition of the estuarine waters of the United States and trace changes in that condition through time,
- Assess the health or condition of the estuarine waters of the various coastal states and trace changes in that condition through time,
- Utilize the approach to identify reference conditions for estuarine waters in the United States, and
- Utilize existing state monitoring programs as appropriate

The geographic extent of the Estuarine / Coastal ProbMon Program is restricted to the eastern-most regions of the state. It is coordinated through the DEQ Central Office in Richmond and is carried out primarily by the Piedmont (PRO - Glen Allen) and Tidewater (TRO - Virginia Beach) Regional Offices. A small proportion of the estuarine probabilistic sites fall within the geographic jurisdiction of the Northern Virginia Regional Office (NVRO) in Woodbridge. Because of the small number of sites involved (1 or 2 sites annually), and logistical and training considerations, PRO assumes the primary responsibility for sampling while NVRO personnel may accompany and aid them in the field.

At the state level, the Virginia DEQ defined its agency goals and objectives relative to its comprehensive statewide Water Quality Monitoring (WQM) Program. Each participating DEQ region (PRO & TRO) needs to complete its assigned probabilistic stations in order for DEQ to reach defensible conclusions about estuarine water quality from a statewide perspective.

Monitoring Design (Site Selection, etc.) :

The sampling strata for tidal tributaries have been geographically defined, by estuary size and drainage location, and a set of randomly selected sampling sites are provided annually by the EPA/ORD Gulf Ecology Division (GED) Laboratory in Gulf Breeze, Florida, upon request.

The two principal sampling strata consist of (1) small tidal tributaries to the Chesapeake Bay and its major tributaries and (2) tidal tributaries and embayments of the Atlantic coast and Back Bay/North Landing River (which discharge into Pamlico/Albemarle Sounds, North Carolina). The major tidal tributaries to Chesapeake Bay (the Potomac, Rappahannock, York and James Rivers) are effectively characterized by the probabilistic monitoring of Virginia's Chesapeake Bay Program.

In the first year of sampling, 35 sites were selected in Virginia's portion of the Chesapeake Bay mainstem and the tidal portions of its major tributaries (Rappahannock River, York River, James River, & Elizabeth River - the tidal portions of the Potomac River mainstem are entirely in the state of Maryland). In order to better characterize smaller estuarine subdivisions, DEQ has in subsequent years emphasized and will continue to emphasize minor tidal tributaries to the Chesapeake Bay, the Atlantic Ocean, and to Pamlico/Albemarle Sound by sampling at 50 sites annually. Virginia's participation in the interstate Chesapeake Bay Program already provides adequate probabilistic monitoring for the characterizations of the Chesapeake Bay mainstem and its major tidal tributaries (e.g., lower Potomac, James, York, and Rappahannock Rivers). The weighting of the current sampling design guarantees that each year approximately 70% of the sites (~35 stations) are selected in the Chesapeake Bay drainage and approximately 30% (~15 sites) are selected in coastal drainages. This will assure that a minimum of approximately 60 sites will be available to characterize the coastal estuary resource class by the end of the fifth year of the program.

Core and Supplemental Water Quality Indicators:

At present, with the resources provided by the EPA NCA/Coastal 2000 Grant, estuarine probabilistic stations are sampled for the complete suite of parameters described in the National Coastal Assessment QAPjP cited above, as well as additional parameters utilized by the Chesapeake Bay Program. The total suite of water column parameters includes profiles of temperature, pH, DO, salinity and photosynthetically active radiation (LiCor), as well as samples for chlorophyll, nutrients and suspended solids measurements at near-surface, mid-depth and near-bottom. In addition, homogenized sediment samples are collected for local (DCLS) analyses of particle size and total organic carbon (TOC), as well as for metals and organic contaminant analyses and toxicity testing at EPA-contracted laboratories. A separate, 0.04 m^2 sediment sample is collected and sieved in the field for the posterior identification of macroinvertebrate benthic infauna species, to complete the sediment 'triad' for 'weight-of-evidence' ecological evaluations and assessments. EPA Grant funds also currently provide for the contracting of the Fisheries Science Laboratory at the Virginia Institute of Marine Science (VIMS) for fish trawls. These trawls are used to collect fish community-structure data, epibenthic organisms, incidental fish for pathological examinations, and targeted fish species for the analyses of metals and organic contaminants in whole fish. (Please refer to the "NCA-C2000 Overview" for an overview of the core ecological and chemical parameters stipulated by the National Coastal Assessment (Coastal 2000) Program and "Estuarine ProbMon Local Parametric Coverage" for a complete list of locally analyzed water column and sediment parameters.) Beginning in the summer of 2003, DEQ started supplementing the NCA core indicators with additional sampling for bacteria (fecal coliforms, E. coli, and enterococci) as well as for dissolved trace metals.

Sample handling and shipping varies with the type of sample and its final destination for analysis. All samples are collected from boats anchored at the monitoring sites and are appropriately labeled and stored on wet ice at 4^{o} C during transport to the responsible DEQ Regional Office. Samples to be analyzed at the Virginia State laboratory (DCLS) are maintained on ice and shipped daily to Richmond by overnight courier service. Such samples are received and processed within 24 hours of collection. Analyses are completed within the holding time specified in the pertinent QAPjPs and EPA analytical method descriptions, after which the resultant data is entered into the DCLS LIMS system. Analytical results are subsequently transmitted to and permanently stored in the DEQ CEDS 2000 database on a daily basis. Turnaround time from sample arrival at DCLS to receipt of analytical data varies from 48 hours to 21 days, depending upon sample type.

Sediment samples that are to be analyzed chemically and toxicologically by EPA-contracted laboratories are held under refrigeration at DEQ Regional Offices and are shipped to Richmond by courier on a weekly basis. Samples from the previous week are united and shipped via overnight air to the EPA Gulf Ecology Division (EPA/GED) laboratory at Gulf Breeze, FL, from where they are redistributed to the appropriate contracted laboratories. Benthic infauna samples are preserved in (10%) buffered formalin as soon as they are collected and are maintained at DEQ Regional Offices until the end of the field season (early October). They are then united at the DEQ Central Office in Richmond and shipped to EPA/GED for subsequent transshipment. Turnaround time for the receipt of analytical results from EPA-contracted laboratories varies from one year to two years or more, depending upon sample type and EPA QA/QC procedures prior to the relay of data to DEQ!

Data related to fish community structure, epibenthic invertebrates, and habitat collected by VIMS trawl sampling, are immediately entered into their onboard SAS database during the process of collection. Target fish species selected for chemical tissue analyses are individually labeled and wrapped and maintained on ice during transport to the laboratory. Once there, they are frozen and maintained until the end of the field season (October). They are then shipped overnight, on dry ice, to EPA/GED for storage and later transshipment. Fish pathology specimens are maintained in Dietrich's solution until the end of the field season and are subsequently shipped to EPA/GED. Fish community, epibenthic macroinvertebrate and habitat data are united into a final report which VIMS sends to DEQ soon after the end of the field season, generally in October or early November. Turnaround time for fish tissue chemical data and fish pathology data from EPA-contracted laboratories is currently at least two years!

Frequency / Duration:

As is typical of probabilistic survey programs, monitoring sites are sampled only once, after which new sites are randomly selected each of the following year(s). Under the conditions defined by the NCA QAPjP, sampling occurs during the summer months, from 1 July through 30 September. This period also coincides with the sampling “window” defined for the use of the Chesapeake Bay Program’s “Benthic Index of Biological Integrity” (B-IBI), which is utilized to evaluate the ecological health of the benthic community.

DEQ’s Estuarine Probabilistic Monitoring Program was proposed and developed as a major component of the agency’s Ambient Water Quality Monitoring Program, and is fully implemented at this time. The resources currently provided by the EPA Coastal 2000 Grant, which facilitated the initiation of the program in 2000, are due to terminate at the end of September 2004, and renewal of federal support for the program is not certain after that date. DEQ is currently evaluating the resource requirements in order to continue the Estuarine ProbMon Program with state funding beginning in 2005, possibly with a reduced suite of parameters.

Quality Assurance Measures:

DEQ’s field and laboratory activities adhere to QA/QC protocols specified in the National Coastal Assessment Field Operations Manual (EPA 620/R-01/003) and the National Coastal Assessment Quality Assurance Project Plan 2001-2004 (EPA/620/R-01/002), except where specific variations have been authorized by the Regional NCA QA Officer. Authorized departures include the use of submerged pumps and hoses for the collection of subsurface water samples and vacuum field-filtration of nutrient and chlorophyll samples. Both of these procedures are specifically described in the corresponding sections of the QAPjP and SOPs for Virginia’s Chesapeake Bay Monitoring Program.

DEQ requires that a minimum of 10% QA samples (field duplicates, field blanks, etc.) be collected at estuarine ProbMon field sites for all locally analyzed parameters. At present, three QA sites are randomly selected annually per DEQ Regional Office, for a total of six QA sites among the 50 sites sampled (12%).

Data Management:

Both samples and the resultant data collected within the National Coastal Assessment Program follow diverse pathways. Standard procedures for the transportation and delivery of samples to the Virginia Division of Consolidated Laboratory Services (DCLS) and of sample shipment to EPA/ORD/GED at Gulf Breeze, FL are described above.

The data flow and data management for water and sediment samples analyzed by DCLS follow pathways and turnaround times as described for the WQM Program in general. Analytical results are QAed by DCLS and stored in their LIMS database. Results that are complete and certified there are subsequently shipped electronically to the DEQ FTP site for upload into the CEDS 2000 database on a daily basis.

Currently, all data from locally (DCLS) analyzed samples reside in DEQ’s CEDS 2000 database. A list of DCLS parameter group codes, analyte names and analyte STORET codes is provided in the table “Matrix of Local Estuarine ProbMon Parameters”. The turnaround time from receipt of samples at the laboratory until data arrives in the database varies from 48 hours to 21 days, depending upon sample type. All analytical results receive a QA review at DCLS, prior to shipment to the DEQ database, and another QA review by programmed algorithms (data range screenings, etc.) within the CEDS database. Data that are ‘flagged’ by the automated screening procedures undergo an additional evaluation by DEQ’s QA Officer. Whatever questions arise concerning the location, date and time of samples arriving at DCLS, or about the accuracy of DCLS data transmitted to the CEDS database, are resolved immediately via e-mail and voice communication between laboratory personnel and monitoring personnel at the DEQ Central or appropriate Regional Office.

Contact: For further information on the Estuarine Probabilistic Monitoring Program contact:

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Freshwater Probabilistic Monitoring

The Commonwealth of Virginia is rich in water resources with a wide variety of aquatic environments from freshwater to saltwater, and in mountain to coastal plain settings. But it is the quality of a resource that gives it value. So, the question that needs to be asked is "How good is Virginia's water quality, and does it vary across the state?" The Virginia General Assembly, environmentalists, citizens, and the USEPA have encouraged the Virginia Department of Environmental Quality (DEQ) to answer this question. DEQ responds from a compliance perspective through the biennial 305(b) Report. This thorough report is based on tens of thousands of data points collected from more than a thousand stations in streams, lakes, and estuaries of the Commonwealth. It provides a comprehensive comparison of these monitored waters to the Water Quality Standards. However, it is based on sample locations selected through the observer's understanding of what samples are needed and knowledge of where to best collect them. This targeted sampling has great utility for monitoring regulatory compliance of pollution sources, identifying impaired waters, and for tracking local pollution events. While point estimates of water quality are made with these data, it is difficult to extrapolate the estimates to unsampled waterbodies or to a geographic area of the Commonwealth for two reasons. First, the sample locations were not randomly determined. Second, the target population is the individual sites themselves and not a region or stream type where all points had an equal chance of being sampled. Consequently, the question about Virginia's water quality cannot be answered accurately for the state as a whole from these ambient data. In response to the need to evaluate water quality in whole river basins and the Commonwealth in general, DEQ added probabilistic monitoring (ProbMon) to its freshwater monitoring program in 2001. The aim of ProbMon is to provide an accurate regional assessment of the chemical, physical, and biological conditions of Virginia's water resources. The station locations have been selected randomly to allow the expression of water quality conditions in statistical terms. That is, a point value can be generated with an estimate of its precision. For example, it is possible to determine the true percent of streams having good water quality with 95% confidence.

ProbMon's focus is on non-tidal perennial streams in Virginia. DEQ's ProbMon survey will collect data from approximately 300 stream locations over a five-year period. The survey is evenly spread over the period 2001-2005, with approximately 60 locations sampled each year, to incorporate wet, dry, and normal years in the database. In the end, the survey will provide policy-makers and the public with estimates of the status of Virginia's aquatic resources with a known level of statistical confidence. It will also describe associations between indicators of natural and anthropogenic stress and aquatic resources. Finally, it will be used to statistically assess the Commonwealth's water resources.

This section of the monitoring chapter analyzes selected ProbMon water chemistry data from autumn 2001 and spring 2002. These two years of monitoring only provide enough data to generally assess statewide conditions. As data is collected during the remaining three years of the study the assessments will become specific for subsets of the Commonwealth's water resources including stream order, river basin, and ecoregion. Although many questions about Virginia's waters can be answered with ProbMon data, not all can be. The reason is, we only get a good estimate of a parameter for some portion of the aquatic resource when the sample size is sufficiently large. The sample design's focus on stream order and on non-tidal streams also put limits on the questions that can be answered. As ProbMon provides responses to long unanswered questions, we may find a future that demands a more thorough undertaking to answer other questions. The results in ProbMon reports will help guide that future.

Monitoring Objectives

ProbMon's goal is to assess the condition of Virginia's non-tidal streams and rivers. The survey provides 1) estimates of the geographic coverage and extent of the aquatic resource conditions with known confidence; 2) estimates of the current status, and a basis to determine trends, and changes in indictors of Virginia's aquatic resources with known confidence; 3) statistical summaries and assessments of Virginia's aquatic resources; and 4) a description of associations between indicators of natural and anthropogenic stressors and the condition of aquatic resources. ProbMon was designed in part to meet requirements of the Water Quality Monitoring and Information Act (WQMIRA 1997) and the JLARC Review (1996). JLARC and WQMIRA specifically encouraged an increase in chemical and biological monitoring, statistical analysis of monitoring data, and statewide sampling comparisons for all water quality criteria. ProbMon specifically provides the foundation for meeting these requests. The sampling design allows for answering a wide variety of questions with statistical accuracy including the following examples.

Policy: What water quality issues need to be addressed?
Science: What types of streams are most threatened and what are the threats?
The Commonwealth's aquatic resources: How many river kilometers meet water quality standards?
The benthic macroinvertebrate community: To what degree do non-tidal waters have balanced, healthy macroinvertebrate communities based on the benthic metrics?

Probabilistic Uses and Limitations

There are several ways to evaluate the quality of streams in Virginia. One method is to survey all the streams in each basin, which would require resources far in excess of current levels, and would also be extremely time-consuming with about 80,000 kilometers (50,000 miles) of streams in Virginia. The basin rotation module in the DEQ monitoring scheme will produce a very coarse census. A second method is to use an empirical model for the water quality in each river basin. Models have to be calibrated and verified based on historical water chemistry records. Such models are also time-consuming and expensive, and currently are ineffective in determining the biological integrity of waters. A third way is to collect data using targeted methods. Targeted monitoring networks have been in place in most states for decades and significant funds have been invested in collecting data from them. Generally, these stations are strategically located at places suspected of having degraded water quality. Examples are above and below the outfall of a wastewater treatment plant or manufacturing facility. Traditional monitoring stations have also been placed where it is easy to sample. For example, most of the Virginia's ambient monitoring stations are at bridges. Data collected in this manner can be used to answer questions such as "Is a manufacturing facility in compliance with its wastewater permit?" or "Should the stream segment be on the Impaired Waters List?" While targeted monitoring is excellent at answering these critical questions, it cannot be used to speculate on the overall condition of the Commonwealth's water resources. The reason is that the ratio of degraded to non degraded waters is unknown. The final monitoring option considered is the probabilistic method, which is used in the ProbMon survey.

The probabilistic method allows DEQ to establish baseline water quality information for river basins, stream types, and geographic areas in the Commonwealth. If the probabilistic study is repeated at a later time, trends in the quality of the resources can also be estimated. Probabilistic monitoring can address regional questions such as "What percent of piedmont Virginia streams have a pH lower than 6.5?" Most important, the estimates can be made with statistical confidence.

Probabilistic Monitoring Design

Probabilistic sampling sites were randomly identified using EPA / EMAP protocols. DEQ provided information on the type(s) of aquatic resources to be sampled and EPA/ORD of Corvallis, Oregon, provided random geographical coordinates to be sampled within stream size classes (Strahler stream order). The Strahler stream ordering system is a general way of describing the size of a stream or river (Strahler 1964). The smallest continually flowing headwater streams are called "first order". When two first order streams join to form a larger stream it becomes a second order stream. Two "second order" streams join to form a third order, and so on. Smaller streams entering a higher-ordered stream do not change its order number. Because Strahler stream order is expected to be an important determinant of aquatic condition, the random selection of sites was arranged so that approximately equal numbers were chosen from 1^{st} - 4^{th} and 5^{th}+6^{th} order streams each year.

To gauge water quality across the Commonwealth, field and chemical data were collected at each ProbMon site (DEQ, 2003b). Dissolved oxygen, pH, specific conductance, and temperature were measured in mid-stream, 0.3 m below the stream surface. Water and sediment samples were collected and sent to the Virginia Division of Consolidated Laboratory Services in Richmond, Virginia for analysis. In all, 79 chemical and physical parameters were measured at each site along with four field parameters. Selected parameters are discussed and the results for these parameters are presented. Although, benthic macroinvertebrates and habitat were sampled at most sites, only conventional pollution parameters are presented in this report.

Data Analysis / Assessment

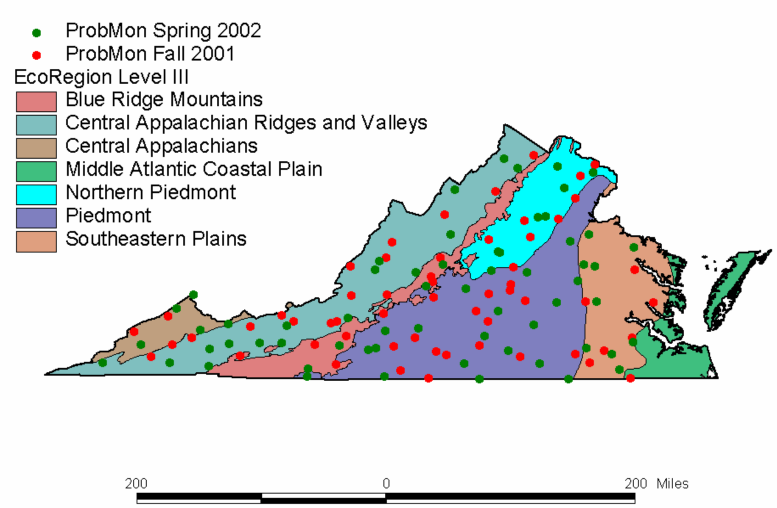
For this report, only a selection (DO, pH, temperature, and bacteria) of the 83 ProbMon parameters were analyzed through box plots, statewide maps, and data distributions. Boxplots were created to compare variables by Strahler order. Most water quality parameters are not normally distributed so the median was used to compare results across stream orders. Boxplots will eventually be used to compare other groupings as well. Maps showing the range of values for a variable across the state are a second method employed to detect patterns. The third method of analysis, following USEPA guidelines, involved the generation of cumulative distribution functions (CDF) for variables (USEPA 2002, Olsen 1999). The CDF is a statistical function that has been underutilized in environmental studies. Formally, it estimates the probability that a variable is less than or equal to some value. It is most useful displayed graphically so the viewer is able to determine the likelihood of any value. However, it can also provide the probability that a variable would be above a threshold or that it would be within a certain range. Importantly, because of the random sampling of ProbMon stations, these probabilities apply to all non-tidal streams in the Commonwealth. A detailed explanation of the CDF is available in the first year ProbMon report (DEQ, 2003).

Freshwater ProbMon Results

First-year results from the ProbMon survey are presented in the complete 2001 ProbMon report, available at the DEQ web site at http://www.deq.state.va.us/water/probmon.pdf.

The analyses presented here are based on data collected in the autumn of 2001 and spring 2002. The map below shows these ProbMon sampling sites against Virginia ecoregions. Ecoregions are areas of uniform climate, topography, and biology that are expected to exhibit differences in chemical and biotic parameters. At present, DEQ has collected too few samples to detect differences among ecoregions.

Figure 2.1-1. ProbMon stations sampled during fall 2001 (n=58) and spring 2002 (n=61) and the ecoregions of Virginia.



Dissolved Oxygen

Dissolved Oxygen (DO) is one of the most important determinants of habitat suitability for aerobic organisms. In streams, the DO concentration is altered by photosynthesis, respiration, nutrient input, reaeration, and temperature, all of which have seasonal cycles. These factors change gradually with the rise in elevation westward across Virginia. This natural variability is reflected in the water classes in Virginia's Water Quality Standards (Table 2.1-1). For example, a high-energy mountain stream in western Virginia (Class V and VI in Table 2.1-1) is expected to have higher DO than a low-gradient, warm water stream in eastern Virginia (Class III in Table 2.1-1). Although expectations vary, all waters in Virginia are required to have a DO of 4 mg/L or above. Streams that support stocked trout or naturally reproducing trout must have DOs of at least 5 mg/L and 6 mg/L, respectively.

Table 2.1-1. DO, pH and temperature standards in Virginia by water Class (Commonwealth of Virginia 1997).

9 VAC 25-260-50. Numerical criteria for dissolved oxygen, pH, and maximum temperature.***

CLASS OF WATERS	DO (mg/l) Min.	DO (mg/l) Daily Avg.	pH	Maximum Temp. (°C)
I Open Ocean	5.0	--	6.0-9.0	--
II Estuarine Waters (Tidal Water- Coastal Zone to Fall Line)	4.0	5.0	6.0-9.0	--
III Nontidal Waters (Coastal and Piedmont Zones)	4.0	5.0	6.0-9.0	32
IV Mountainous Zones Waters	4.0	5.0	6.0-9.0	31
V Stockable Trout Waters	5.0	6.0	6.0-9.0	21
VI Natural Trout Waters	6.0	7.0	6.0-9.0	20
VII Wetlands	*	*	*	**

*This classification recognizes that the natural quality of these waters may fall outside of the ranges for D.O. and pH set forth above as water quality criteria; therefore, on a case-by-case basis, criteria for specific wetlands can be developed which reflect the natural quality of the waterbody.

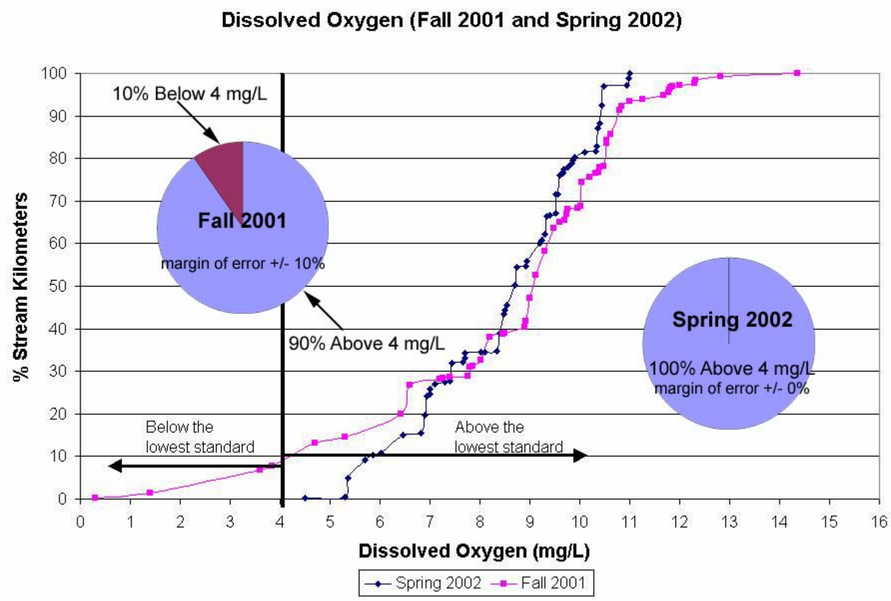
**Maximum temperature will be the same as that for Classes I through VI waters as appropriate.

***The water quality criteria in 9 VAC 25-260-50 do not apply below the lowest flow averaged (arithmetic mean) over a period

Seasonal variations in DO concentration are directly related to temperature. Higher summer temperatures tend to produce lower DO concentrations because DO solubility is inversely proportional to temperature. During the winter months, most aquatic organisms have a lower metabolism and aquatic plants have died back so the demand for oxygen is less. In the summer, fish and aquatic insects require an adequate level of DO for feeding, growth, and reproduction. In addition, in the summer aquatic plants flourish and elevate DO levels in sunlight, but depress them in the dark.

Pollution plays an important role in DO concentration. Human and animal waste released into streams act as fertilizers. As microbes break down the organic matter, their respiration depletes the available DO so that aquatic animals may become stressed and die.

Figure 2.1-2. CDF curves and pie charts of DO from Fall 2001 and Spring 2002.



The utility of the CDF curve is that probabilities can be directly determined from the figure because the vertical axis is a cumulative probability. That is, it shows the chance of a DO value being the same size or smaller than that listed on the horizontal axis. Assuming the data in Figure 2.1-2 is representative of all Virginia non-tidal streams, we can pose questions such as “What percent of Virginia non-tidal streams had a DO below 4 mg/L during fall 2001?” To answer the question, on the figure draw a line up from the DO value of 4. Where the line intersects the fall 2001 CDF curve, draw a horizontal line to the vertical axis. The value on the vertical axis is approximately 10%. Then, the answer to the above question is, “10% of Virginia non-tidal streams have a DO less than 4 mg/L.” Because the data set contains only 58 measurements, there is error associated with the answer. The confidence interval lines (not shown in Figure 2.1-2) for the fall DO data occur at approximately 0% and 20% and represented the margin of error. See the first year Probmon Report for these confidence intervals. This means the precise answer to the above question is that between 0% and 20% of the streams have DO less than or equal to 4 mg/L with 95% confidence.[5] The confidence intervals would narrow significantly as additional data are collected**.**

The two sampling periods covered by this report afford the opportunity to compare seasonal differences for the state. For example, (see Figure 2.1-2) during the spring 2002, the DO was above 4 mg/L 100% of the time. In the fall DO fell below 4 mg/L 10% of the time. Although we are uncertain of the underlying reasons for the difference, we suspect it is a seasonal phenomenon rather than interannual climatic variation.

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5 When setting upper and lower limits for a statistic, a certain percent of the time the parametric value of the statistic will be contained within those limits a specified percent of time. Thus, a 95% confidence interval in the figure suggests that in 95 out of 100 times we collect data and construct the intervals, they will include the statistic. It is incorrect to say the statistic is contained in the interval 95% of the time; the interval changes, not the statistic (Sokal & Rohlf 1981).

Figure 2.1-3. Spatial distribution of DO in Virginia's ecoregions

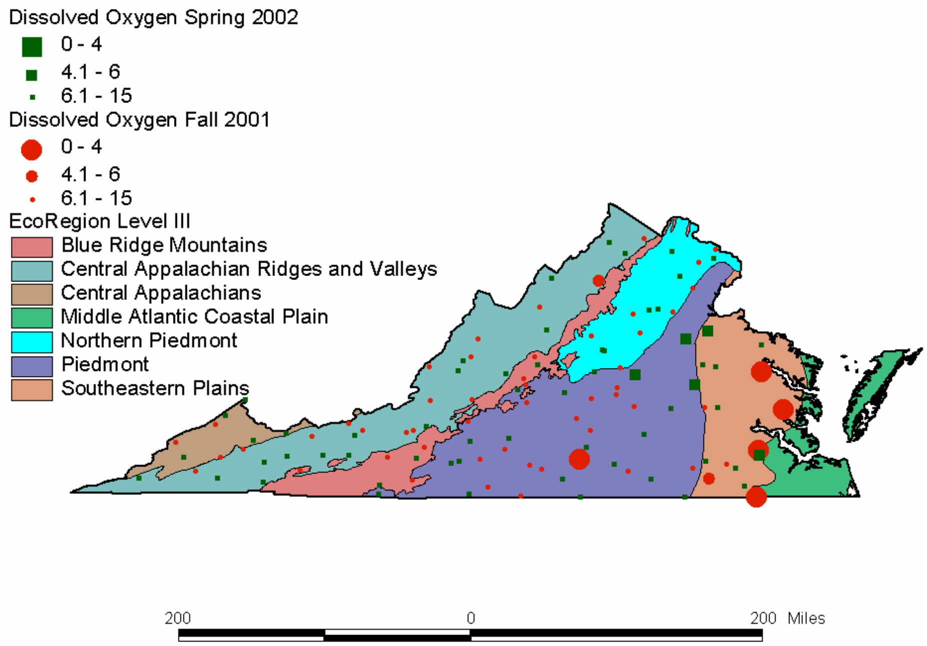
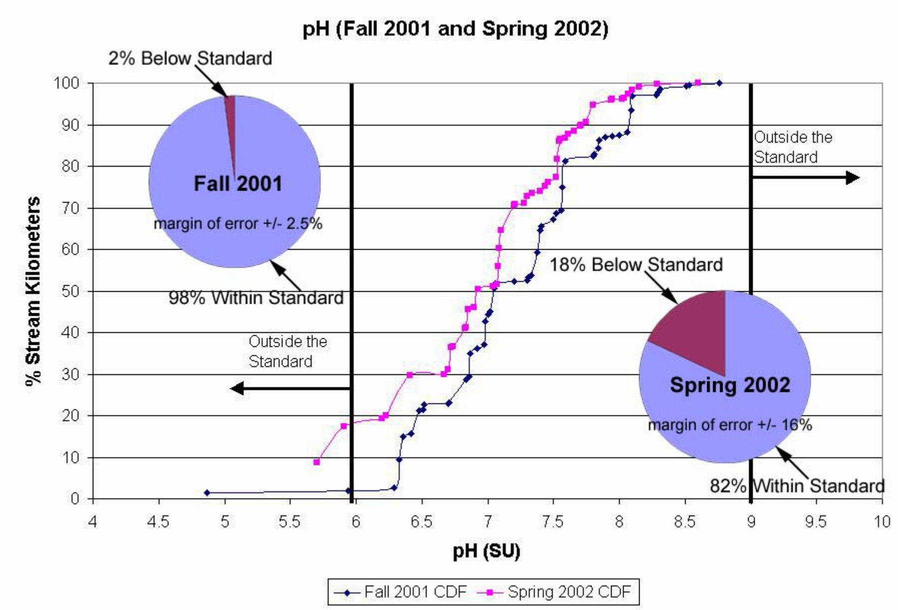


Figure 2.1-3 displays the DO measured across Virginia where larger dots and squares signify lower DOs. Several low concentrations occur in the Southeastern Plains and Middle Atlantic Coastal Plain ecoregions in the piedmont and tidewater areas. Streams in the east typically have a lower gradient so that snags, leaf packs, and fine sediments dominate the habitat. Lower gradient streams are slower moving and therefore have lower turbulence, reaeration and DOs. In addition, median temperatures are higher in the Piedmont and Southeastern Plains ecoregions. Because these warmer eastern waters have lower DO solubility they are expected to have lower DO concentrations. During the Fall of 2001, severe drought may have contributed to low DO concentrations across the state.

pH

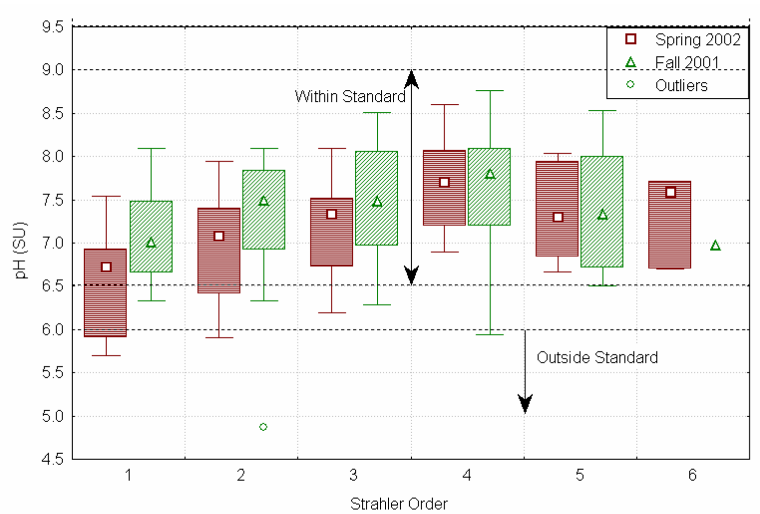
One of the primary indicators of water quality is pH. Stream pH depends on local ecology, the presence of inorganic and organic acids, and anthropogenic influences. Most aquatic organisms can withstand a pH as low as 6, but prefer a range between 7 and 8.5 (Barker et al. 1990). pH values harmful to aquatic life-use are the extremes; below 5 or above 9. This is reflected in Virginia's water quality standards, where all waters must have a pH range from 6 to 9 (Table 2.1-1), or 6.5 to 9.5 in certain streams identified in the WQ Standards. pH standards may also be determined case-by-case for natural conditions as in swamps and other wetlands (Commonwealth of Virginia 1997).

Figure 2.1-4. CDF curves and pie charts of pH from Fall 2001 and Spring 2002



The regulatory pH boundaries are indicated on the CDF graph for pH in Figure 2.1-4. Based on the data collected thus far, pH violations are few in Virginia streams. Six sites had low pH readings. They were located in blackwater streams in eastern Virginia where the pH is naturally low due to the leaching of organics in these wetland-influenced streams. From the pH CDF curve in Figure 4, only 2% of sites sampled in the fall of 2001 had a pH below the lower regulatory limit of 6.0 and no streams exceeded the upper limit of 9.0. Spring 2002 probabilistic data showed 18% of Virginia non-tidal streams were below the pH standard. Again, the confidence intervals are quite large and predictions will be more refined as sampling continues. For now it appears pH violations occur on the acid side of the scale at a frequency that may be seasonally dependent.

Figure 2.1-5. Boxplot of pH from Fall 2001 and Spring 2002.



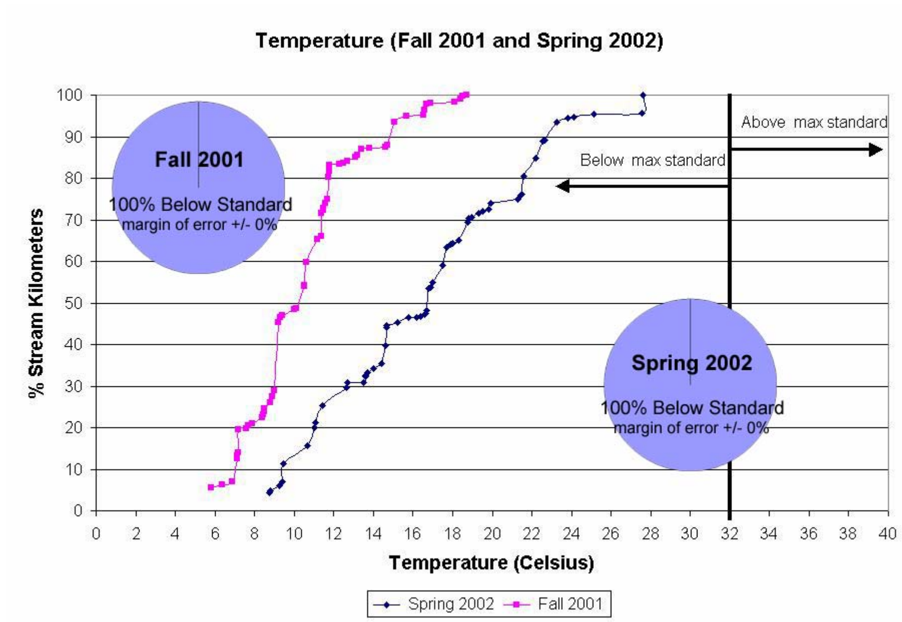
Box plots for pH by stream order are graphed in Figure 2.1-5. However, the medians suggest that pH initially increases from 1st through 4th order streams and declines in higher orders. Most stream orders tend to exhibit lower pH in the spring. Future samples will help determine whether this is a consistent pattern.

Temperature

Temperature affects water quality by imposing a heat burden on aquatic life, and by limiting the level of dissolved gases in water. Temperature in streams varies in relation to seasonal and daily changes. Sunlight is the primary source of temperature change. However, stream temperature is also influenced by the temperature of the streambed, groundwater inputs, and air in contact with the water surface. Temperature is inversely related to bank vegetation cover; less cover implies more exposure to the sun and higher temperature. Also, water temperature reflects the colder winter temperatures compared to the summer. Deviations from this trend occur especially in springs or in small streams. Also, runoff from impervious surfaces in urban areas typically increases water temperature. Finally, the effluent from dischargers tends to be warmer than the receiving stream and may elevate water temperature.

Stream temperature has a major effect on aquatic organisms. It can directly influence the types of organisms found in an aquatic system as well as their growth, behavior, metabolism, reproduction and feeding habits. The standards for water temperature reflect the maximum preferred temperatures for different forms of aquatic life across Virginia (Table 2.1-1).

Figure 2.1-6. CDF curves and pie charts of temperature from Fall 2001 and Spring 2002.



The majority of non-tidal freshwater streams in Virginia are designated Class III (coastal and piedmont zone waters) or Class IV (mountainous zone waters). The maximum temperature, a Class III water should not exceed is 32°C and a Class IV water should not exceed 31°C. Based on the CDF curve in Figure 2.1-6, all ProbMon sites from fall 2001 and spring 2002 had temperatures below 32°C. Therefore, it is expected that nearly 100% of state waters are in compliance with temperature standards during the fall and spring seasons. These predictions will be further refined in the final ProbMon report through separate CDF curves for mountain and piedmont provinces.

Figure 2.1-7. Spatial distribution of measured water temperature.

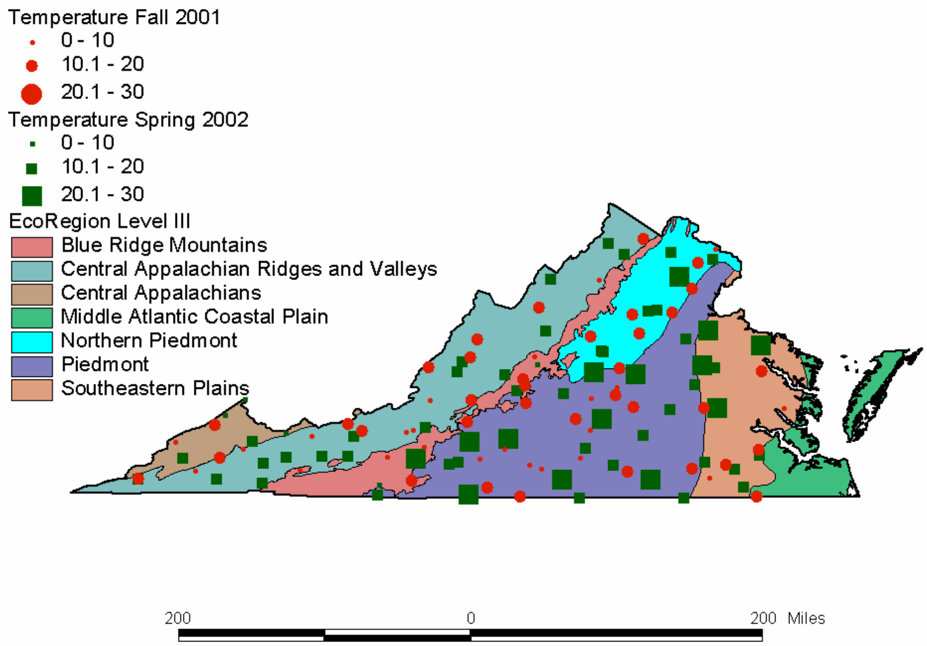
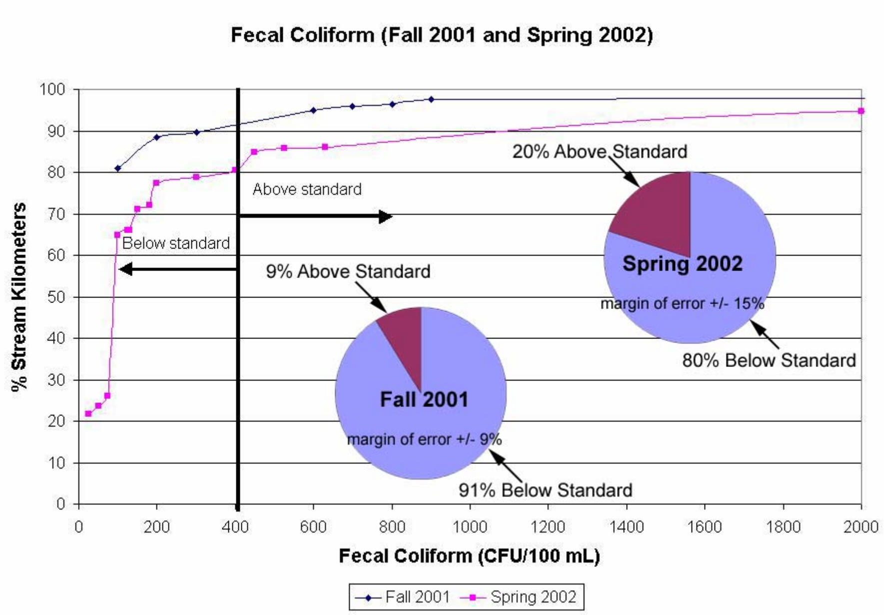


Figure 2.1-7 displays relative temperatures across the state. Large symbols indicate locations where water temperature was higher in the fall of 2001 (circles) and spring of 2002 (squares). Based on Figure 7, higher temperatures are found in the Piedmont and Southeastern Plains ecoregions. Stream temperatures are expected to be higher in these areas because of land use and lower altitudes. The mountainous ecoregions, that is, the Central Appalachians and Appalachian Ridges and Valleys, also tend to have lower temperatures because the streams are more rural or forested with more natural inputs.

Fecal Coliform Bacteria

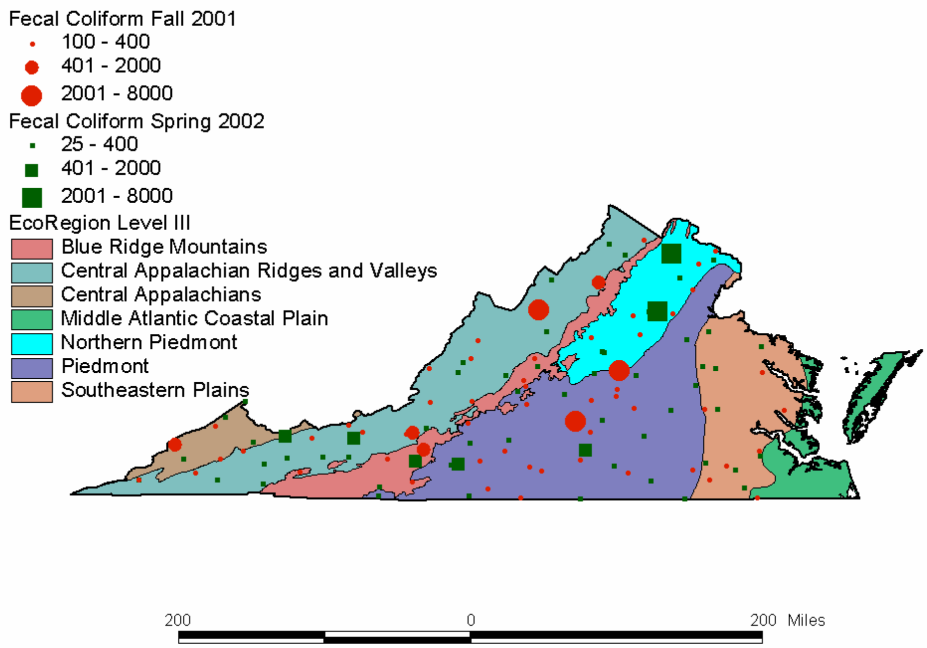
High counts of fecal coliform bacteria in a stream indicate that feces have entered the stream presenting the risk of human disease from pathogenic organisms. Fecal coliform bacteria are found in the fecal matter of all warm-blooded animals. By the Virginia water quality standard, a stream cannot exceed a geometric mean of 200 colony forming units (cfu) per 100 ml when sampled two or more times over a calendar month. The instantaneous standard is no more than 10 % of the samples in a calendar month exceeding 400 cfu/100 ml. *Escherichia coli* (*E. Coli*) became the official standard statewide in January 2003, but was not sampled during the first two years of ProbMon.

Figure 2.1-8. CDF curves and pie charts of fecal coliform bacteria from Fall 2001 and Spring 2002.



The bacterial count CDFs are graphed in Figure 2.1-8. In the fall of 2001, 81% of the counts were below the detection limit of 100 cfu/100 mL. At that time, approximately 9% of Virginia stream kilometers exceeded the interim bacteria standard of 400 cfu/100 mL. During spring 2002, nearly 20% of all Virginia stream kilometers exceeded the interim bacteria standard. These point estimates are currently very rough estimates; the confidence interval bounds are quite broad. Nevertheless, it is highly interesting that spring exceedences are approximately double those in the fall. Different hydrological regimes from spring to fall combined with land use differences could explain the elevated bacteria levels during the spring season. In highly agricultural areas spring rainstorms tend to wash accumulated bacteria-laden feces off pastures and manure-fertilized fields. The mechanism behind these seasonal differences needs to be explained as data accumulates.

Figure 2.1-9. Spatial distribution of fecal coliform bacterial samples.



Based on the bacteria map of the Commonwealth and its ecoregions in Figure 2.1-9, there is no relationship between bacterial counts and ecoregion except that high counts tend to occur in the middle and western parts of Virginia.

Conclusions

One annual cycle of ProbMon data are discussed in this chapter based on date collection in fall 2001 and spring 2002. All sites were randomly selected by the USEPA using a stratification method developed in the EMAP program (Diaz-Ramos et al. 1996). The great value of random sites is that the estimates from the data apply to the entire population. Here, the population is the non-tidal waters of Virginia. Water chemistry was sampled at 58 sites in the autumn of 2001 and 61 sites in the spring of 2002.

The cumulative distribution function (CDF) was used with the chemical data to generate probabilities of a value being smaller or larger than a selected value. In this report CDF graphs were used to determine the chance of DO, pH, temperature, and bacteria values in Virginia's streams violating state water quality standards. The method also provides confidence limits that are important gages of the precision of the statistic. For these first two years, the estimated confidence limits for environmental conditions are fairly wide. That is, they are imprecise. As more data are collected the confidence limits will narrow. This will allow more precise estimates of the parameters of interest to facilitate the intelligent management of Virginia's aquatic resources.

Future Trends

In this brief glimpse into Virginia's ProbMon program, only a fraction of the program's data could be presented. ProbMon collects biological data using EPA's Rapid Bioassessment Protocols (RBP). A goal of DEQ's biomonitoring program is to increase the number of reference sites across the state so that reference conditions can be translated into a multimetric index for macroinvertebrate communities. The data collected at random sites in the ProbMon program will accelerate this process and help refine reference conditions throughout the Commonwealth.

The Virginia ProbMon survey includes a habitat assessment component to determine the percent of non-tidal streams that have exceptional quality as well as the percentage of degraded streams. Habitat data are collected using the RBP visual habitat assessment methods. These methods use qualitative scoring that is subjective but comparable statewide when performed by trained biologists. In some regions of the state, biologists collected additional quantitative and qualitative habitat data. The goal of collecting quantifiable physical habitat data is to separate the difference between anthropogenic and geologic processes in channel adjustment (Rosgen, 2001). One of the more elusive parameters to quantify is increased sediment supply to streams (Kappesser, 2002). According to Rosgen several factors control river channel form, principally streamflow, sediment regime, riparian vegetation, and direct physical modifications. Quantifiable physical data can predict an increase of sediment supply over natural conditions.

The freshwater ProbMon program also collects and analyzes the land cover data upstream of ProbMon sites. The land surrounding a water body can significantly impact in-stream water quality, and thereby alter the physical habitat and biological community. DEQ intends to create a filtering matrix of habitat and chemical data to identify potential reference sites using land cover data. As ProbMon evolves, the quantity and variety of habitat data collected will expand to better define the range of physical habitat, and to allow the detection of relationships between physical habitat, biological communities, land cover and water quality.

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Fish Tissue and Sediment Monitoring Program

DEQ monitors concentrations of chemical contaminants, including heavy metals and organic pollutants, in fish and shellfish tissue in order to assess the human health risks for individuals who may consume fish from state waters. Additionally, sediment samples are also collected at each sample station and are analyzed for the same pollutants. The sediment data are used to help locate a source of pollution where the fish tissue data indicate a concern. The sediment data are also used to identify potentially impaired aquatic ecosystems.

In the fish tissue-monitoring program, a two-tiered sample strategy is followed which is consistent with federal guidance for fish tissue contamination monitoring programs.

Tier I is a screening study of a relatively large number of sample stations to identify sites where concentrations of contaminants in the edible portions of fish indicate potential health risks to human consumers. Sediment samples are also collected to assess whether stream sediments are contaminated to a degree that poses a potential for aquatic ecosystem impairment. Tier I stations are selected using a rotational river basin approach of all the river basins in Virginia. Until 1996, approximately 25-30 stations were selected among two river basins each year as the routine monitoring. The Code of Virginia § 62.1-44.19.5 requires maintenance of the 1996 level of tissue and sediment sampling which equates to a minimum of 24 fish sample stations per year. Since 1996 the following number of stations have been sampled for fish and sediment; 1997, 43 stations, 1998, 54 stations, 1999, 58 stations, 2000, 72 stations, 2001, 96 stations, 2002, 98 stations with a variable number of some additional stations sampled for sediment each year.

Several criteria are used to select the sample stations and include correspondence with the DEQ-Waste Division to identify contaminated waste sites that may impact tissue and sediments in aquatic environments. These are regional office recommendations, extensive literature searches, important recreational and/or commercial fisheries (Department of Game and Inland Fisheries, 1996), close proximity to point source discharges, and coverage of the entire watershed, i.e. headwater as well as higher order streams. Routinely, a minimum of three species of fish (top level predator such as a largemouth bass, mid-level predator such as a bluegill, and a bottom feeder such as catfish) are collected at each station. Edible filets from five to ten adult specimens of each species are composited into one sample, resulting in a minimum of three tissue samples per station. Depending on availability of additional funds and variability of species available, four or five species may be sampled at some stations.

Tier I analytical results for fish tissue are expressed in wet-weight and are compared to contaminant screening values that are computed using EPA risk assessment techniques for noncarcinogen and carcinogen effects. The screening values are calculated based on the same toxicity values and assumptions for average fish consumption rate, body weight and an acceptable extra cancer risk of 10^{-5} that were used in calculating the Virginia water quality criteria designed for the protection of human health from consumption of contaminated fish. These screening values represent the fish tissue concentration that the water quality criteria are intended to protect against. Occasionally, additional pollutants are sometimes detected in fish tissue for which Virginia does not have water quality criteria; or the toxicological information on the chemical has been revised and the water quality criterion has not been updated yet. In this case, an updated screening value is calculated and used to assess the data.

Analytical results for contaminants in sediments are expressed in dry-weight and are compared to effects range-median screening values provided by the National Oceanic and Atmospheric Administration to assess the potential effects of sediment contamination to aquatic life.

For additional information and data from previous years of sampling visit the DEQ website at **http://www.deq.state.va.us/fishtissue/html.**

If tier I results indicate problems may exist, then a second more intensive tier II study is initiated to determine the magnitude and geographical extent along with potential source(s) of contamination in the fish and/or sediment.

The program fulfills the Clean Water Act § 106 United States Environmental Protection Agency (EPA) grant requirements for the collection of fish tissue and sediment. Data generated by the program are used by the Virginia Department of Health to determine the need for fish consumption advisories and/or bans. Data are also used by the DEQ and other state and federal agencies to assess the environmental quality of Virginia's waters. The following is a list of those compounds analyzed.

Metals:	**Pesticides**:	
Arsenic	Aldrin	Endosulfan (alpha)
Beryllium	Dieldrin	Endosulfan (beta)
Cadmium	Endrin	Total PCBs
Chromium	DDT	Toxaphene
Copper	DDE	Benzene hexachloride (alpha)
Lead	DDD	Benzene hexachloride (beta)
Mercury	Chlordane	Lindane
Nickel	Heptachlor	Benzene hexachloride (delta)
Selenium	Heptachlor epoxide	Chlorpyrifos-methyl
Silver	Hexachlorobenzene	Mirex
Thallium	Methoxychlor	Oxychlordane
Zinc	Nonachlor	Pentachloroanisole
	Dicofol	Polybrominated diphenyl ethers (BDEs)

Other Organics:

Acenapthane	Diethylphthalate	Total PAHs
Acenaphthylene	Dimethylphthalate	Benzo (e) pyrene
Anthracene	Fluoranthene	Benzo (b) fluoranthene
1,2 Benzanthracene	Fluorene	Benzo (a) anthracene
Benzo (a) pyrene	Ideno (1,2,3-cd) pyrene	Benzo (g,h,I) perylene
3,4 Benzofluoranthene	Naphthalene	Benzo (I) fluoranthene
Benzo (k) fluoroanthene	4,6-Dinitro-2-methylphenol	
1,1,2, Benzoperylene	N-Nitrososdiphenylamine	
4-Bromophenyl phenylether	N-Nitroso-di-N-propylamine	
4 Chloro-3-methylphenol	Phenanthrene	
2-Chloronaphthalene	Bis (2-ethyl-hexyl) phthalate	
4-Chlorophenolphenylether	Butylbenzylphthalate	
Chrysene	Di-N-butylphthalate	
Dibenzo (a,h) anthracene	Di-N-octylphthalate	
3,3-Dichlorobenzidine	Pyrene	
2,4-Dimethylphenol	1,2,4-Trichlorobenzene	

Benthic Macroinvertebrate Monitoring Program

The Biological Monitoring Program (BMP) utilizes the study of bottom dwelling macroinvertebrate communities to determine overall water quality. Changes in water quality generally result in changes in the kinds and numbers of these animals that live in streams or other waterbodies.

The majority of the freshwater benthic macroinvertebrates found in Virginia come from four general groups: insects, mollusks, crustaceans, and annelid worms. Besides being the major intermediate constituent of the aquatic food chain, benthic macroinvertebrates are "living recorders" of past and present water quality conditions. This is due to their relative immobility and their variable resistance to the diverse contaminants that can be introduced into streams. No two groups of benthic organisms have the same limiting factor for the various chemical and physical constituents encountered in the aquatic ecosystem. The community structure of these organisms provides the basis for the biological analysis of water quality.

The BMP is composed of 150 to 170 stations that are examined annually during the spring and fall. Qualitative and semiquantitative biological monitoring has been conducted by the agency since the early 1970's. The US EPA Rapid Bioassessment Protocol (RBP) II was employed beginning in the fall of 1990 to utilize standardized and repeatable methodology. The RBP's produce water quality ratings of nonimpaired, slightly impaired, moderately impaired and severely impaired instead of the former ratings of good, fair and poor.

The procedure evaluates the macroinvertebrate community by comparing ambient monitoring “network” stations to “reference” sites. A reference site is one which has been determined to be representative of a natural, unimpaired waterbody. The RBP evaluation also accounts for the natural variation noted in streams in different ecoregions. One additional product of the RBP evaluation is a habitat assessment. This provides information on the comparability of each stream station to the reference site.

Citizen Monitoring

Citizen water quality monitoring has been a stewardship activity in Virginia for many years. As the amount of citizen-collected water quality data has increased, so has the interest in using these data for more than background information in Virginia's water quality assessments. In the past, citizen organizations established stream monitoring programs with limited support from the Commonwealth. A statewide organization, the Virginia Save Our Streams Program of the Virginia Division of the Izaak Walton League of America (VA SOS), took the lead in establishing relations with the Department of Environmental Quality (DEQ) and the Department of Conservation and Recreation (DCR) to develop a statewide citizen monitoring program. This was done through two separate letters of agreement signed by each agency in 1998 and was furthered by a three-way agreement signed in 1999. A new letter of agreement was signed in April 2002 to renew the collaborative partnership and to add a new signatory, Alliance for the Chesapeake Bay, to the partnership. In 2002, the Virginia General Assembly passed legislation that established the Virginia Citizen Water Quality Monitoring Program in the *Code of Virginia* (§62.1-44.19:11). Additional citizen monitoring information can be found on the DEQ website: **http://www.deq.state.va.us/cmonitor**.

The positions of the Citizen Monitoring Coordinator within DEQ and the Community Watershed Stewardship Manager within DCR were created to provide guidance and technical support to citizen monitoring organizations, facilitate communication among citizen monitoring organizations and other agencies, promoting the use of citizen water quality monitoring data in a manner consistent with the data use goals of the organization and encouraging additional citizen monitoring efforts. In addition, the Citizen Monitoring Coordinator is responsible for collecting citizen-generated data for DEQ use. This role has facilitated the use of citizen-collected data in Virginia’s 305(b) Water Quality Assessment Report.

In addition, a budget amendment in the 1999 Virginia General Assembly Session created the Citizen Water Quality Monitoring Grant Program to fund citizen monitoring activities when funding is available. This grant program has provided funding to 54 different organizations since 1999. The financial support from the Commonwealth has greatly enhanced the quality and quantity of citizen-collected data.

Currently, there are approximately 80 organizations throughout the Commonwealth with active citizen water quality monitoring programs. These programs vary in sophistication and in parameters monitored but all citizen-generated data are important in characterizing the state of Virginia's waters. Citizens monitor streams, lakes, and estuaries for a variety of parameters depending upon the goals of their program and the financial resources available. Common ambient measures include any of the following physical and chemical parameters: water temperature, pH, dissolved oxygen, nutrients (various forms of nitrogen and phosphorus), or solids suspended in the water column. Biological parameters measured by citizen monitors often include benthic macroinvertebrates, fecal coliform bacteria, or chlorophyll *a*.

While all citizen-collected water quality data throughout the state are important, data used in this report were collected under documented protocols, standard operating procedures, and quality assurance/quality control procedures approved by DEQ for water quality assessment purposes. Data collected where the exact sampling location could not be confirmed were not used in this assessment. Data collected by citizen volunteers can also assist water quality agencies in prioritizing future monitoring and restoration work. Additional information associated with citizen monitoring assessment issues can be found in the 2004 Water Quality Assessment Guidance Manual found on the DEQ website: **http://www.deq.state.va.us/wqa**.

In order to assist citizen monitoring organizations with developing monitoring programs, the *Virginia Citizen Water Quality Monitoring Methods Manual* was printed and distributed to organizations involved in water quality monitoring. The manual can be found on the DEQ website: **http://www.deq.state.va.us/cmonitor**. This manual provides guidance to organizations on quality assurance/quality control procedures and protocols acceptable to DEQ for use in this assessment report.

VA SOS has a benthic macroinvertebrate citizen monitoring protocol that is widely used by many affiliate organizations. In 2000, VA SOS completed a two-year study, funded by DEQ, evaluating this protocol and developing a new protocol to more closely correlate with professional methods developed by EPA and used by DEQ. VA SOS began training volunteers in the modified protocol in 2001 and most volunteers have been switched to this method. Data collected by VA SOS and affiliate organizations using both methods were used in this assessment.

The VA SOS protocol is suitable for monitoring higher gradient streams with riffles typical of those found in the western part of Virginia. In response to requests from citizens located in the eastern part of Virginia, VA SOS has established a committee to develop a protocol for low gradient, freshwater, nontidal streams. This committee is in the final stages of developing this protocol.

Cooperative partnerships have enhanced relationships between state agencies and citizen monitoring organizations which has improved the quality and quantity of citizen-collected data for this report. This foundation is expected to continue and be built upon in the future.

DEQ would like to thank all of the organizations listed below for submitting citizen-collected data and supporting documentation for development of this report:

Alliance for the Chesapeake Bay
Assateague Coastal Trust
Audubon Naturalist Society
Appomattox River Water Quality Monitoring Program (coordinated by Clean Virginia Waterways and Longwood University)
Culpeper Soil and Water Conservation District
Environmentally Concerned Citizens Organization (ECCO)
Friends of Claytor Lake
Friends of the North Fork of the Shenandoah River
Friends of Powhatan Creek
Friends of the Shenandoah River
Guest River Project
Historic Green Springs, Inc.
Hoffler Creek Wildlife Foundation
Lake Anna Civic Association
Loudoun Soil and Water Conservation District
Loudoun Wildlife Conservancy
Mattaponi and Pamunkey Rivers Association
Maury River Alliance
McClure Group
North Fork Goose Creek Watershed Committee
Page County Water Quality Advisory Committee
Pedlar River Institute

Piedmont Region TMDL Initiative
Smith Mountain Lake Water Quality Monitoring Program (coordinated by Ferrum College and the Smith Mountain Lake Association)
Staunton-Augusta Chapter of the Izaak Walton League
Upper Levisa River Restoration Project
Upper Rappahannock Watershed Stream Monitoring Program (coordinated by the Culpeper and John Marshall Soil and Water Conservation Districts)
Virginia Save Our Streams Program of the Virginia Division of the Izaak Walton League of America

The Alliance for the Chesapeake Bay submitted ambient (chemical and physical) data collected by individuals and the following affiliate organizations:

Caledon Natural Area
Cat Point Creek Group
Cherokee Lake Association
Chesapeake Bay Foundation, York Chapter
Chesapeake Bay Youth Conservation Corps
Chippokes State Park
Eastern Shore Soil and Water Conservation District
Elizabeth River Project
Friends Of Chesterfield's Riverfront
Friends of the Rappahannock
Friends of Scott's Creek
George Washington's Birthplace National Monument
James River Association
James River Park
Leesylvania State Park
Mason Neck State Park
Mattaponi Indian Reservation
Tidewater Resource Conservation and Development Council
Westmoreland State Park
York River State Park

The Virginia Save Our Streams Program of the Virginia Division of the Izaak Walton League of America submitted benthic macroinvertebrate data collected by individuals and the following affiliate organizations:

Amelia County Landfill
Bluestone Watershed Committee
Buchanan Citizens Action Group
Buckingham Citizen Action League
Cowpasture River Preservation Association
Douthat State Park
Elliott Creek Watershed Protection Council
Emory and Henry College
Environmentally Concerned Citizens Organization
Environmental Education Center
Friends of the North Fork of the Shenandoah River
Friends of the North River
Friends of Page Valley
Friends of the Pedlar River
Friends of the Rappahannock
Friends of the Rockfish River
Grundy High School Earth Science Class
Headwaters Association
Holston River Water Quality Monitors
Hungry Mother State Park

J. R. Horsley Soil and Water Conservation District
Kittrell Stream Team
Maury River Middle School
Maury River Monitors
Mountain Stream Stewards
Middle River Monitors
Northern Virginia Soil and Water Conservation District
North Fork Goose Creek Watershed Committee
Pedlar River Institute
Piedmont Environmental Council
Radford University Green Team
Reston Association
Rivanna Conservation Society
Rivanna River Basin Project
Skyline Chapter of Trout Unlimited
StreamWatch
Upper Rappahannock Watershed Stream Monitoring Program
Virginia Museum of Natural History at Virginia Tech
Virginia's Explore Park
Virginia Tech Student Chapter of the American Water Resources Association
Walker Creek Watershed Group
Warren County Chapter of the IWLA

In the river basin summaries, several terms are used in the citizen monitoring descriptions that are defined as follows:

- Ambient monitoring: Monitoring for physical and chemical water quality parameters
- Benthic macroinvertebrate monitoring: Careful observations of the macroinvertebrate (bottom-dwelling insects and crustaceans) community in a stream can give an indication of long-term water quality conditions.
- Certified VA SOS volunteers: VA SOS program volunteers that have gone through the training and testing process as identified in the VA SOS Quality Assurance Project Plan